The Implications of Cognitive Style for the Implementation of Analytic Models *

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1. Introduction

A common topic in management literature over the past few years has been the difference between managers and management scientists, usually in relation to the argument that their association has not been a productive one. A recent article by a disillusioned academic-turned-bureaucrat compares the situation with C.P. Snow's famous notion of the Two Cultures of science and the humanities: "Managers and management scientists are operating as two separate cultures, each with its own goals, languages and methods. Effective cooperation -- and even communication -- between the two is just about minimal."[1] Perhaps this is an overpessimistic viewpoint, but it is one that is expressed very often and by individuals who have substantial experience with the use of analytic methods in management.

Management science techniques have been very successful in particular areas of business, such as logistics planning, resource allocation problems, financial forecasting, etc. It appears that these techniques have on the whole found the applications for which they are best suited and managers who were instinctively receptive to Operations Research in the days when it was new, promising and largely incomprehensible soon latched onto them and by now have integrated their use into day-to-day operations. However, in other areas of business they have been unable to gain any real foothold. Most obviously, they have had little impact on what one might term decision-making under vagueness -- the many management problems which do not lend themselves to explicit formulation, where there are ambiguous or overlapping criteria for action and where the manager himself operates through "intuition." A major issue for management science as a discipline now seems to be how to get managers in such situations to make use of the formal techniques that so clearly can help them and yet in practice have not done so. There seem to be two main factors relevant to this problem. One is the actual techniques available to

be used; obviously, process chemists are very ready to use linear programming because it suits the constraints and nature of the problems with which they have to deal. That factor, however, is surely secondary. The main theme in all the articles discussing why management science has not had the expected impact on general managers' decision-making concerns the differences in approach and behavior between the two cultures. The distinguishing feature of the management scientist is his ability to provide techniques, though obviously these techniques take time to evolve. What is less controllable, either by the manager or the scientist, is the fact that each has a distinctive style of thinking and of problem-solving that is in its own context very effective but which is also not easily communicated to an individual who does not share this style. A number of researchers have pointed to particular aspects of thinking and personality that differ between people that build and people that use models; this has been a consistent topic in Churchman's work[2] and more recently, Huysmans and Doktor[3] have provided useful experimental data. In a way it is platitudinous to state that managers and scientists are different, but a reason for focusing very explicitly on that fact is that many writers argue that the way to bridge the gap between the two groups is for each to become a little more like the other. In this view it is the differences themselves that are the problem: "education" is generally recommended as the solution -- the manager should be trained in elementary quantitative techniques and the scientist in interpersonal and managerial skills. (Grayson strongly argues in this direction.)

This paper is explicitly about the differences in thinking between the two cultures. It has some suggestions to make as to how the manager and the scientist can best work together in the development of analytic models and decision aids. However, it does not in any way argue that the differences

in thinking are either bad or good; they simply exist. More importantly they appear to be stable aspects of personality and growth that emerge from one's overall experience. They each have strengths and potential weaknesses; the issue for the manager and scientist is how to complement each other's strengths and how to communicate with each other. The very differentiation of thinking style is what makes each of the two successful in his chosen specialization, but as Lawrence and Lorsch have so well pointed out,[4] the cost of differentiation is the increased difficulty it presents in integration.

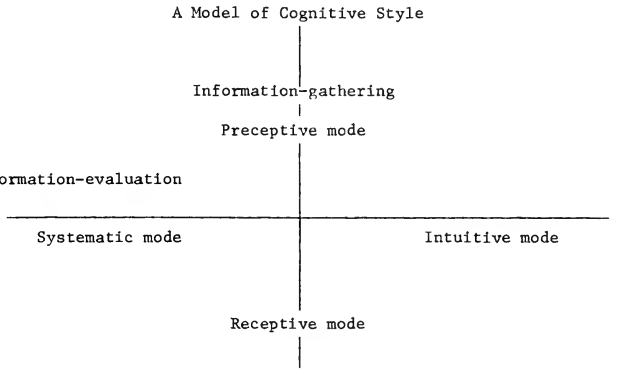
Over the past four years the authors have developed and tested out a model of cognitive style, drawing on the excellent work in developmental and cognitive psychology that has in recent years reinvigorated the whole study of thinking and problem-solving.[5] A main aim has been to better understand the cognitive aspects of the decision process; we regard analytic models essentially as prosthetics that amplify the user's problem-solving strategies. Given that premise, it seems that the central factor determining whether or not a model will be successfully implemented -- that is that the manager will actively use it in reaching a decision and will feel willing to use similar decision aids in the future -- is the extent to which it "fits" the manager's style of thinking. The main body of this paper largely defines what is meant by "fit."

The section below provides a brief, formal statement of the model in terms applicable to problem-solving and decision-making, in general, rather than just to analytic techniques. This statement has the baldness of a prospectus; it is followed by a discussion of the experimental data we have gathered in validating it. The central section of the paper extends our findings to the specific topic of implementing formal analytic models.

2. A Model of Cognitive Style

The model views problem-solving and decision-making in terms of the processes through which individuals organize the information they perceive in their environment, bringing to bear habits and strategies of thinking. It argues that consistent modes of thought develop through training and experience; these can be classified along two dimensions, one of information-gathering and one of information-evaluation. Figure 1 below shows the resulting paradigm.

Figure 1



The information-gathering dimension relates to the essentially perceptual processes by which the mind organizes the diffuse verbal and visual stimuli it encounters. The resultant "information" is the outcome of a complex coding that is heavily dependent on mental set, memory capacity and strategies -- often unconscious ones -- that serve to ease "cognitive strain." Of necessity, information-gathering involves rejecting some of the data encountered, summarizing and categorizing the rest. Preceptive individuals tend to bring to bear concepts that they use to filter data;

they focus on patterns of information, look for deviations or conformities with their expectations. Their precepts act both as cues for information-gathering and as heuristics for cataloguing what they find. By contrast, the Receptive thinker is more sensitive to the stimulus itself. He will focus on detail rather than pattern and tries to derive the implications of the data from direct examination instead of from its fitting his precepts. Each mode has its advantages in specific situations; equally, each includes risks of overlooking the potential meaning of data. The Preceptor too easily ignores relevant detail while the Receptor may fail to shape detail into a coherent whole. In management positions, the Receptor will be most successful in tasks such as auditing and the Preceptor in many marketing or planning roles.

The second dimension, information-evaluation, refers to processes commonly subsumed under the term "problem-solving." Individuals differ both in how they use data in reaching a decision and in the sequence of their analysis. These differences are most pronounced in relation to planning; Systematic thinkers tend to approach a problem by structuring it in terms of some method which if followed through leads to a likely solution. Intuitive thinkers usually avoid committing themselves in this way; their strategy is more one of hypothesis-testing and trial-and-error. They are much more willing to jump from one method to another, to discard information and to be sensitive to cues that they may not be able to identify verbally. Here again, each mode of evaluation has advantages and risks. In tasks such as production management the Systematic thinker can develop a method of procedure that utilizes all his experience and that economizes on effort. An Intuitive thinker in such a task often reinvents the wheel each time he deals with a particular problem. By contrast, the Intuitive is better able to approach

ill-structured problems where the volume of data, the criteria for a solution or the nature of the problem itself do not allow the use of any predetermined method.

Most modern theories of the decision process tend to stress "rationality." Mathematical decision theory and game theory, for example, are both mainly concerned with defining what rational behavior should consist of. Accounting for the discrepancies between that and observed behavior is only a secondary aim. Other theories, particularly those focusing on decision-making in its organizational context, include factors of motivation, personality and social forces but still tend to treat decision-making as essentially equivalent to problem-solving. This viewpoint is particularly prevalent in the work of H.A. Simon and his associates, whose theory is of dominating influence on recent research. In the cognitive style model, the focus is also on problem-solving, but the central argument is that decision-making is above all situational. Whereas "problems" (in the academic sense) come neatly packaged with -- usually -- a right answer and with instructions on what the problem-solver should try to do, decision-making includes problem-finding. The manager scans his environment, organizing what he perceives. His efforts are as much geared to clarifying his values and intents as with dealing with predefined problems. Obviously, some problems do force themselves on his awareness; this is particularly true in crisis situations. Nonetheless, he generally has some discretion in the exact problems or tasks he chooses to deal with and in the level of aspiration he sets for himself; his aspiration often determines the extent to which he involves himself in terms of effort and personal risk. The manager's activities are bounded mainly by the formal constraints of his job position

and by the more informal traditions and expectations implicit in his role. Because of this, his decision-making activity is strongly influenced by his perceptions and a decision "situation" exists when he observes and interprets some event or cue in his environment that activates him into the search-analyze-evaluate sequence that results in a choice of decision. This sequence is initiated by and depends on this assessment of his environment. The cognitive style model provides some explanation of the processes affecting this assessment and thus includes an important aspect of behavior omitted in most theories on decision-making, that of problem-finding, problem-recognition and problem-definition. Generally, most other cognitive theories assume the situation has been defined; the manager is thus presented with the packaged problem. (Mathematical decision theory, for instance, presents techniques for evaluating a problem given it has been or can be thus defined; here a decision is viewed as a gamble.)

Implicit in the focus on problem-finding is the concept that particular modes of cognition are better suited to certain contexts than others. The central argument of this study is that there needs to be a fit between the decision-maker's cognitive style and the information-processing constraints of his task. Given this fit, the manager is more likely to gather information from the environment that leads to successful or at least comfortable problem-finding. He should also be able to evaluate that information in a way that facilitates successful problem-solving. The implications of a misfit are perhaps easier to indicate. It was suggested earlier that a Receptor focuses on inductive meaning from detail rather than deducing implications from pattern. A field sales manager who receives a wide range of information may well be flooded by it if he is a Receptor.

He cannot examine all the sales reports, orders, salesmen phone calls, etc., etc. He needs to filter his information and to be alert to trends and discrepancies. For example, it may be the combination of sales of a particular product in Region X together with a saleman's recent report of several customers' comments that leads him to recognize signs of changes in consumer taste. The Preceptor is particularly suited to situations such as this, where the manager must have a concept of his environment. The Receptor would not in general be able to maintain the dynamic relation of data items to each other that shapes these patterns. Equally, however, he does not jump to conclusions or overlook detail; a Preceptive manager relies on doing so and would thus be much less successful in a task such as auditing, where it is vital not to ease the strain of data-gathering by using precepts as filters. Similarly, it is easy to envisage tasks where the Intuitive thinker cannot come to terms with the data that is of necessity required in his decision-making (e.g., this month's production cost, output and scheduling figures) because he is unable to think in terms of a sequential, methodical program of analysis.

The term "style" was chosen rather than the more common one of cognitive "structure" to stress that modes of thinking relate more to propensity than capacity. An individual's style develops out of his experience; there seems to be a reinforcing pattern, particularly in late high school and in college, for a student increasingly to choose courses that build on his strengths; this in itself further develops those strengths and also perhaps atrophies the skills in which he is less confident. There is some research to confirm this pattern.[6] It suggests that not only are there tasks that are suited to particular cognitive styles, but also the capable individual will search out the tasks compatible with his cognitive

propensities. He will, in addition, generally approach tasks and problems using the mode of thinking most comfortable for him.

This statement of the model implies some testable hypotheses about how individuals of particular styles approach problems and data. The list below summarizes the main characteristics of each style.

Systematic thinkers tend to:

look for a method and make a plan for solving a problem

be very conscious of their approach

defend the quality of a solution largely in terms of the method

define the specific constraints of the problem early in the process

discard alternatives quickly

move through a process of increasing refinement of analysis

conduct an ordered search for additional information

complete any discrete step in analysis that they set out on

Intuitive thinkers tend to:

keep the overall problem continuously in mind

redefine the problem frequently as they proceed

rely on unverbalized cues, even hunches

defend a solution in terms of "fit"

consider a number of alternatives and options simultaneously

jump from one step in analysis or search to another and back again

explore and abandon alternatives very quickly

Receptive thinkers tend to:

suspend judgment and avoid preconceptions when looking at data

be attentive to detail and to the exact implications of a piece of data

insist on a complete examination of a set of data before deriving conclusions

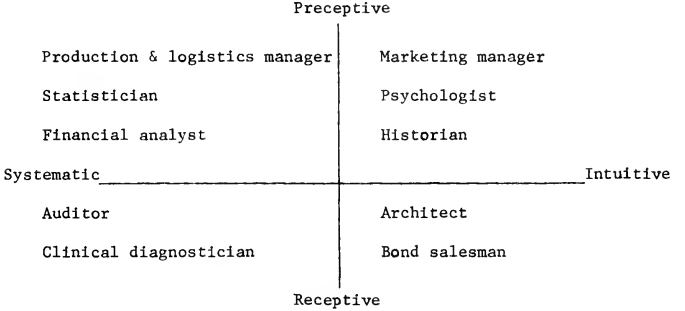
Preceptive thinkers tend to:

look for cues in a set of data

focus on pattern and

jump from one section of a data set to another, building a set of explanatory precepts

The authors' research suggests that particular tasks and roles are more suited to one cognitive style than to another. The diagram below shows careers that seem especially compatible with the skills and predispositions implicit in each quadrant of the cognitive style paradigm:



3. Experimental Results

We have carried out a range of experiments over the past two years aimed at validating the assertions made in the preceding statements.[7] Most of these experiments have used samples of MBA students at the Harvard Business School. The homogeneity of these samples has been offset by the advantages they provide for control over factors of age, motivation, experience, etc.

The main effort in the experiments has been to identify and measure cognitive style. A set of twelve standard tests developed by ETS, New Jersey[8] was administered to 107 subjects. Each test was specifically

chosen as being suited to one particular mode of style. The results confirmed most of these implicit hypotheses; factor analysis showed structures and loadings corresponding closely to the dimensions of the model. The scores did not correlate with any general set of cognitive skills such as visual or verbal activity (although the tests used to identify the Intuitive mode were in fact verbal) or IQ. More importantly, 70% of the sample showed distinct differences in level of performance on the Systematic as against the Intuitive tests or the Receptive as compared with the Preceptive. This supported the basic argument that individuals would tend to have a definite "style." There is a very real difficulty in choosing cutpoints on psychometric scales;[9] we chose a conservative approach, classifying a subject as "Intuitive" or "Systematic," etc., only when his scores on tests requiring, say, an Intuitive response were substantially different from that on the tests measuring capacity for the other mode of style along that dimension. The comparisons focused on relative, not absolute, performance; the numeric scores were converted to a one to seven scale, with a "1" indicating that the subject scored in the lowest seventh of the sample and a "7" corresponding to the top seventh. The factor analysis was repeated using a separate earlier sample drawn from the same population. Several of the tests used in the main analysis were not included in this group's set of tests but the factor analysis produced very similar structures and loadings.

From the main sample, twenty students whose test results indicated a distinct cognitive style were picked out and asked to take part in a follow-up experiment. This made use of a "cafeteria" of problems, a set of sixteen open-ended problems from which subjects were asked to pick out five to answer. The sessions were tape-recorded and were held on an

individual basis. Subjects were invited, though not required, to talk aloud as they dealt with each problem. The results point to distinct differences in the ways in which individuals of particular styles respond to problems. The Systematic subjects tended, as expected, to be very concerned with getting into a problem by defining how to solve it. They were conscious of their planning and often commented on the fact that there were other specific ways of dealing with the problem. By contrast, the Intuitive subjects tended to jump in, try something and see where it led them. They generally showed a pattern of rapid hypothesis-testing, abandoning lines of exploration that did not seem profitable. The two approaches were easy to identify from the transcripts of subjects' oral responses. More importantly, each mode was effective on particular problems. In one, requiring decoding a ciphered message, the Intuitive subjects solved the problem -- sometimes in dazzling fashion -- while none of the Systematics was able to do so. In this particular case, there seemed to be a pattern among the Intuitives of a seemingly random testing out of ideas followed by a necessary incubation period in which the implications of these tests were assimilated and then a sudden jump to the answer. While it was very easy to follow the Systematics' line of reasoning, there were often unexplained shifts in the Intuitives', who also were much more likely to respond to problems orally rather than writing down their answers -- this provided some confirmation for the idea that Intuitive individuals use their own talking aloud to cue their activity and to alert them to possible lines of analysis.

There were distinct differences in the problems chosen by each of the two groups and in the ones they selected as being most enjoyable.

Their ratings of which problems they enjoyed most were remarkably consistent. The Systematics preferred problems that were programmable, in Simon's sense of the term, while the Intuitives most liked the more open-ended ones, especially those that required ingenuity or opinion.

The overall results of the experiments provided definite evidence both in support of the model of style and of the classification methods developed through the main sample test scores. The verbal protocols in particular highlighted the degree to which these subjects consistently and distinctively respond to problems; there seems little doubt that in these extreme cases at least the individual maps himself onto the problem, rather than fitting his behavior to the constraints and demands of the task as Simon and the Carnegie school suggest.[10] The Systematic subjects generally were strongly Systematic whether that suited the problem or not, and similarly with the Intuitives.

In a secondary set of experiments using the main sample of 107 students, the relation between cognitive style and personality was examined, through comparisons of performance on the test battery with the results of the Myers-Briggs Type Indicator, which uses concepts of personality derived from Jung's theories.[11] It is interesting to note that Mason and Mitroff in their recent article, "A Program for Research on Management Information Systems,"[12] also suggest that the Myers-Briggs Indicator be used to classify individuals in relation to information systems. The most striking result of this experiment was that while the scores on the Myers-Briggs scales showed virtually no correlation with absolute performance on the tests, there was a relationship between cognitive style and those scales. In particular the Systematic subjects were very likely to be Thinking in type and the Intuitives much more

likely to be at the other end of the dichotomous scale, Feeling. Mason and Mitroff provide a useful summary of the differences between the two types:

> "A Thinking individual is the type who relies primarily on cognitive processes. His evaluations tend to run along the lines of abstract true/false judgements and are based on formal systems of reasoning. A preference for Feeling, on the other hand, implies the type of individual who relies primarily on affective processes. His evaluations tend to run along personalistic lines of good/bad, pleasant/unpleasant and like/dislike. Thinking types systematize; feeling types take moral stands and are interested and concerned with moral judgements."

The relation between style and this dimension of type was by far the strongest single feature in the experimental results. There was a more modest relationship between the Systematic style and Introversion and similarly between the Intuitive style and Extraversion. The sample size and the use of nominal categories (Style and Type) prevented us factoring out the impact of the Thinking-Feeling type from the other scales of type; that dimension dominated the results. Our findings mesh well with Mason and Mitroff's predictions (they do not report any experimental data) about psychological type and information systems.

The final experiment, conducted a full year after the others but also using MBA students as subjects, examined the relation between style and career choice. Eighty-two students completed the cognitive style test battery and the Strong Vocational Interest Blank.[13] The results again showed consistent differentiations between Systematic and Intuitive subjects. We compared the career preferences of the two groups and also looked at the cognitive style test scores of those individuals who showed a strong preference for particular careers. (Most of the tests made used non-parametric techniques, particularly the Mann-Whitney U-test.) The Systematic students were much more attracted to administrative careers, to Production, the military and to occupations

involving planning, control and supervision. The Intuitive group's choices centered around professional occupations and the more open-ended business functions; they differed particularly from the Systematics in their preference for Psychologist, Advertising Executive, Librarian, teaching positions and the Arts.

The overall result of all these experiments is to support the model and that of course has been the essential aim. The existence proof now having been made, we plan to extend our experiments and to study real managers in real businesses and, more especially, real model-builders and model-users. We feel that we have established the validity of our conceptual scheme. More importantly, over the course of the experiments and more informally in discussions with managers and other researchers we have found that the model does seem to provide a useful and insightful framework for examining the role of cognitive processes in decision-making.

4. The Implications of Cognitive Style for the Implementation of Analytic Models

One of our major conjectures, that partly underlay the whole development of our model, has been that computer systems in general are designed by Systematic individuals for Systematic users. Although management science has lost its early tones of missionary zeal of bringing "right" thinking to the ignorant, the implementation of analytic techniques not unreasonably tends to reflect the scientist's own distinctive approach to problem-solving. The Systematic individual is above all methodological. The Systematic subjects in the cafeteria experiment "get into" a problem by making a plan for solving it. Their verbal protocols are full of statements like, "There are two ways to do this problem," or, "The problem really is. . ." These are rarely

if ever found in the Intuitives' protocols. Model-building, from the viewpoint of the management scientist, involves making explicit the causal relationships in a particular situation and articulating the problem until he gets a reasonably predictive model; he will then generally refine that model. He has a faith in his own plan and process and his specialized style of thinking enables him quite literally to build a model, shaping ideas and concepts into a methodological whole and above all articulating relationships that the manager may understand but not be able to make explicit. The scientist's skill is indeed a specialized one; the powerful organizing, systematizing capacity he brings to model-building is his special contribution. It is obvious that it can be a vice rather than virtue in specific situations; what D.H. Heany[14] calls the "have technique, will travel" banner under which he feels members of TIMS and ORSA have often marched, really amounts to the rigorously Systematic individual's preference for a systematic approach to all problems in all contexts.

There are many Systematic managers. Our hypothesis is that most of the general managers who currently make substantial use of management science techniques are likely to be Systematic in style. The techniques match their own innate approach to problems and -- as the experimental results with the Strong Vocational Interest Blank suggest -- they gravitate to occupations that are suited to their style. Thus, inventory control is a task that can be systematized, will tend to attract to it Systematic managers and will therefore be an area in which management science techniques will find fruitful ground. By contrast, advertising is not so easily systematized and advertising managers will tend to be Intuitive in style; these techniques do not therefore complement the way in which they deal with

problems. This line of argument points to a "fit" between the cognitive demands of a particular task and the cognitive style of the manager. As was mentioned earlier, the implications of a misfit are perhaps easier to point to; an Intuitive approach to production scheduling is not likely to be either comfortable or successful.

We have found it useful to describe tasks -- and problems in general -- in terms of a taxonomy that classifies the individual's assessment of the extent to which he knows what information is relevant and how he will operate on the information.[15] This provides four basic classes of problems:

Figure 2

A taxonomy of problems

Information manipulation - Conceptual	Information acquisition - Perceptual process: Known	Unknown
Known	Type 1 PLANNING	Type 2 INTELLIGENCE-SEARCH
Unknown	Type 3 INVENTION	Type 4 RESEARCH

The four classes are easily illustrated. If, for example, a manager encounters a problem of inventory control, in which he feels that he knows what data is relevant to the problem and what mental operations and analysis are required to deal with that data, then the problem is one of Planning; he simply implements a program, and his whole effort involves arranging the data into a form into which it can be used as input to a defined, sequential process of evaluation.
A second class of problem, Type 2 in Figure 2, exists when the operations and methods required are known, but not the data involved. Price forecasting

in complex markets is an example of this situation. Before a forecast can be made, a mass of heterogeneous data on economic, price and market variables must be organized and sifted. The forecasting procedure is simple once this has been done. A very different state of affairs exists when the individual understands the data but does not know how to manipulate it. Many production scheduling problems fall into this class, Type 3, of Invention. The relevant factory data is known and the problem consists of finding a "way" of achieving some desired end-point. The fourth class of problem is one where both information and operations are unknown. In this situation, of Research, there is a conscious seeking for cues and generation of explanatory concepts together with the development of a method for manipulating the data thus organized. The development of new products is a typical such problem. Many management science projects start as Research. For example, modelling a complex environment such as the housing market in order to make industry or demand forecasts generally requires a complicated first step in which two areas of the problem are worked on in parallel, the generation of concepts that "explain" reality and that identify the variables of most relevance and, at the same time, the definition of outputs, aims and implementation of the model.

The Systematic individual is attracted to and most comfortable with problems of Planning. In the cafeteria experiment, the Systematic group tended to choose Planning problems and the one problem rated most enjoyable by well over half the group was almost quintessentially Planning in nature. The Systematic management scientist can often take a Research problem and shift it to one of Planning. The methodological formalization he provides helps translate unknown states of perception and conception into known ones. However, there is sometimes the danger that he will

force the translation; he may insist on some objective function that does not really fit the situation partly because his preference for Planning leaves him unwilling to accept "unknown" states. An Intuitive manager may find this insistence both unrealistic and irritating.

Just as the management scientist's specialized style of thinking provides very definite strengths in specialized tasks, so too does the Intuitive manager's. It is important again to stress that the Intuitive mode is not loose thinking; it seems to have an underlying discipline at least as coherent as the Systematic's though less apparent. There is a range of situations where the volume of information, the lack of structure in the task and the uncertainty of the environment make the Intuitive manager's style highly effective. Such situations defy planning and programming. For example, there is no way for any manager to forecast consumer tastes for furniture styles systematically. He can, however, build a set of cues and flexible hypotheses that may alert him to shifts in taste. He may also use the rapid scanning and testing for a sense of "fit" among the disparate items of information he has that is the main characteristic of the Intuitive. More importantly, he need never make his concepts and methods explicit; unlike the model-builder he can act without making any conscious articulation of his premises. An amusing instance of this fact occurred in many of the early efforts to use process control computers in paper-making. The computer experts "knew" the paper-makers knew how to make paper, so that all that was needed was to articulate their decision process. This process turned out to rely mainly on the operators' tasting the broth and putting their elbows to the bearings of the machines to control the

paper flow. For a long time this well-established and highly effective human decision process defied conversion into formal and explicit mathematical terms. The operators were somewhat unhelpful. They "knew" what worked; they had built up out of their experience a clear but not conscious sense of the process. This sense often varied with the individual. When a shift changed the new crew might well reset the valves and modify the whole operation of the machine, asserting that the changes were needed because of the time of day. There was no articulated set of concepts or methods by which this assertion could even be tested. The "decision-makers" here -- and they merit the term since controlling the paper-making process is a constant series of evaluations, assessments and actions -- were able to act efficiently even though they could not articulate their own procedures. This fact became a problem only when it was necessary to build an explicit model of their process.

The management scientist is often in the position of the computer experts in the example above. He needs to make the implicit explicit; the manager may approach the problem for which the model is to be built not with a need to understand the process but more wanting to become aware of what he can trust in order to make useful predictions. This can be useful to the scientist, in that if he can build a model that "works" the manager may well be very ready to use it even though he does not understand it. The central issue, however, is how he can validate the model and determine if he can in fact trust it. The scientist validates his model formally and methodologically; he can test it in relation to known inputs and outputs. In general he will have faith in his plan, in his own systematic process. The manager will validate the model experientially and will test it against some of his own concepts and

expectations. He places much less faith in external "authority." The difference here between the two styles corresponds very closely to that between the Thinking and Feeling types, quoted earlier.

The differences between the manager and scientist in terms of style may often lead them each to treating a particular project as an entirely different class of problem. The management scientist may try to structure the problem to reduce the unknowns and to define very explicitly all the constraints in the situation. He aims at a model that is complete and has predictive power. He will wish to improve and refine the model. That is essentially how he regards "problem-solving." It may be, however, consciously or not, that the manager is most concerned with using the model to give him a better sense of the problem itself. He focuses on -- and enjoys -- playing around with the unknowns until he gets a feeling for what steps are needed; he is then ready to delegate the process of dealing with the problem to some individual who can systematically handle it in a more routine fashion. While the scientist may view the model as a representation of "reality" the manager may wish only for an opportunity to get experiential insight. Before the model has been finally implemented it may have served its purpose for him. He may have grown to understand what the "real" problem actually is. The scientist may feel somewhat piqued at finding that after six months of effort the manager now dismisses the model as not accurate. He himself always defines the problem clearly at the start; he needs a clear definition even to build a model let alone use it to reach a decision. The Intuitive manager does not define problems in this way. He may in fact resent being forced to do so.

There is no need to belabor the issue here; the world hardly needs another paper saying that managers and management scientists deal with

problems differently. The only justification for such a paper is recommendations for action. If the line of argument here is valid, it is clear that the solution to the difficulties the two groups have in working together will not be obtained by trying to blur the differences. The Intuitive manager may learn what network optimization is, but that is unlikely to make him think in the same Systematic mode as the scientist, who is in turn unlikely to develop Intuitive responses through any form of education. (This is not to say that cognitive style is fixed, but to reinforce the point that individuals who have very distinctive styles in specialized areas of activity have strengths that are directly related to their style -- it seems unlikely that the cognitive specialist will change easily or that he should do so in any case.) The real solution seems to lie in two areas: the first concerns the definition of the role of the model within the larger decision process in the particular situation and the second, the question of how to validate the model. From this, the manager and scientist together may better control the process of building the model, the structure of the model itself and their mutual expectations and actions. At the root of both these areas of concern is the whole question of trust and communication, less in the interpersonal than the cognitive sense.

The management scientist's role can be one of Product or of Service. It is important that he decide which it needs to be in a particular situation. If the manager wishes to use a model to help him clarify his own sense of the issues and options then there is no point in trying to provide him with a meticulous and complex simulation. He does not intend to use the model as the basis for his decision; in fact, the model may simply help him decide what the problem is and can then be thrown away

(or written up for an article).[16] On the other hand, he may need a Product rather than a Service; for example, a financial forecasting model, once validated, may be used by a manager as the main basis for ongoing decisions and in some cases he may in effect delegate the actual decision itself to the model. The degree and direction of the management scientist's efforts will be very different depending on how he perceives the manager's needs in the situation. He can only identify these needs by asking a series of questions:

> How does this manager approach problems? What is his cognitive style?
>
> How does he define this problem -- as one of Research, Planning, etc.?
>
> What does he want the model for -- for purposes of his own learning or to make a specific decision?

The answer to each question has distinct consequences. If, for example, the manager's response to problems is Systematic then the model should explicitly reflect this fact; the scientist should invest substantial time in explaining to him the underlying assumptions as to method; the two can afford to invest time and discussion on how the problem should be structured. Here the manager is essentially looking for a technique and the scientist is the expert, with a catalogue of methods. If, however, the manager is Intuitive in style, the scientist should recognize that the model must, if it is to be of use to him, allow the manager to range over alternatives and hypothesis-testing in the fashion that fits his natural mode of problem-solving. In this context, J.A. Botkin has used the paradigm of cognitive style in designing an interactive computer system designed to appeal to Intuitive subjects. He identified five features necessary in the structure of the system to accomplish this:

1) the user should have the ability to create an arbitrary order of processing; the system should not impose a "logical" or

step-by-step sequence on him. "This lack of set sequence allows the Intuitive user to follow his instinct of developing his ill-defined information plan directly from environmental cues." [17]

2) the user should be able to define and explore "scenarios" that may be "played" to generate cues or test trial solutions.

3) he should be able to shift between levels of detail and generality

4) he should have some control over the forms of output and should be able to choose visual, verbal, numeric displays at varying levels of detail

5) he should similarly not be constrained to providing input in a predefined and specific form; he should, for instance, be able to provide commands such as, "Repeat the last step increasing X by 10%."

Botkin's experiment shows fairly clearly that the Intuitive subjects in his sample used his CRT model (which taught the BASIC programming language) very differently from the Systematics; the differences correspond on the whole to those found in the cafeteria experiment. The Intuitive group, measured along various dimensions, seemed to learn from the system and enjoy using it as much as the Systematics. Even though his model was a special case, his results suggest that a modest additional effort on the part of the model-builder in considering how the manager will use the model -- in terms of process rather than of output -- will provide large dividends.[18] Here again, there is a distinction between Service and Product. Where the manager is most concerned with the recommendattions he can derive from the model the sort of cognitive amplifiers Botkin provides are unnecessary. However, where the manager wants the model to help him clarify his own understanding or

definition of the situation it may well be essential to build them into its formal structure. The management scientist needs to consider what a "good" model is; for himself, goodness is largely a quality of predictive power and technical elegance while for the manager it is more a concern of compatibility and comfort -- of the "fit" between how he approaches the problem and how the model allows him to do so.

Perhaps more important even than recognizing the relevance of the user's own problem-solving process on how he will use the model is the whole question of trust. Very often the manager does not get involved in the model itself; he simply asks for the outputs. He may well wish to validate the model by testing out some "scenarios" for which he presumably has some expectations of how the model should react. John Hammond suggests that the model-builder should recognize that in a large and complex model, the user will have no desire or ability to understand its mechanics; the designer must provide him some other way of testing out -- of building trust in -- the model. He recommends [19] that the management scientist should therefore aim "to get something simple and useful up and running as soon as possible. By skillfully manipulating the resultant model the management scientist should be able to obtain results that will give great insights about the problem and its nature and its alternatives to the manager. These insights should cue the mind of the manager and cause him to perceive the problems and alternatives differently which will in turn affect the priorities and direction of the management science effort....Thus the management scientist, too, will learn about the nature of the problem and also about the nature of the manager's perception of it." This recommendation seems particularly

relevant in cases where the manager's cognitive style is highly Intuitive. For relatively little effort and minimal commitment to a particular definition and design, the manager can obtain the initial exploration and hypothesis-testing that may lead him to be able to articulate his assessments of the problem -- or, better, to enable the management scientist to deduce them for him.

These recommendations are all fairly modest, which is to their advantage since it means they may also be feasible. Essentially, they argue that manager and scientist should look at process rather than output -- if they do this the techniques will look after themselves. It seems of central importance for each of the two to recognize that they have a distinctive style of problem-solving that is not necessarily either good or bad, and should then accept that difference. If the management scientist can anticipate the fact that the manager does not in his decision process use the conscious planning that is so natural for himself, he will be less likely to assume that the manager's reluctantly given statement of what the problem is has any permanent force. The manager can recognize a good plan, if he can validate it at some point in his own terms; the scientist's responsibility is the plan and also facilitating the validation. The manager's responsibility is to make very clear to himself first and then to the scientist what he wants the model to do and to be. If he asks for an optimization program for a facilities planning project, he should decide well in advance what he will do with the results. If he knows that he will not make his decision on the basis of the model's output, he should make sure that the design process and the model structure allow him to use the model to amplify his own thinking.

The Intuitive manager can make use of formal analytic techniques only if he can validate them; this validation may in time come simply from a built-up trust in the management scientist as an individual. The Intuitive is very happy to relinquish the mechanics of technical aids to the expert, but only after he has developed confidence in him. It is in this sense that the common recommendation of educating the manager in quantitative skills seems so inadequate. The Intuitive manager will learn to make use of these skills supplied by others, but this learning is internal and informal. More than anything, he needs to learn how to tell a good model from a bad one; the management scientist may have reason for regarding his model as "good" because it satisfies a range of external criteria. For the manager, a good model is one that he can make sense of by testing his own scenarios. However haphazard and unorganized this may seem to the Systematic scientist, his model will be used only if it allows the manager to make these tests or if the process of designing it has done so on a more ongoing basis. He should remember that the sloppy-thinking marketing executive who cannot define his own industry environment pulls in $50,000 a year, has an outstanding track record and makes effective decisions even though he cannot explain quite how he does so.

The arguments of cognitive style presented in this paper are basically relativistic and management scientists, being Systematic, are not relativists. People in general tend to assume that there is some "right" way of solving problems. Formal logic, for example, is regarded as a correct approach to thinking, but the oral transcripts in the cafeteria experiment do not contain any examples of "logical" thinking;

they show instead, among Systematics and Intuitives alike, a reliance on concepts and methods built up over a period of time out of one's assimilated experience.[20] Thinking is always a compromise between the demands of comprehensiveness, speed and accuracy. There can be no best way of thinking. If the manager and the management scientist can recognize first that they each have a different cognitive style and thus a different way of solving the same problem, then their dialogue seems more likely to bear fruit. Our own model of style is not necessarily either complete or precise; we suggest, however, that it does provide a useful way of focusing on the implementation of analytic models for decision-making and a means of developing strategies of action on the part of the management scientist that are much more likely to succeed than those based on concepts of technique, education and salesmanship. We anticipate that members of this audience may feel that the trouble with managers is that they do not think like management scientists. Our comment is:

1) they certainly do think differently

2) so they should

3) we all have to live with that fact.

References

1. C. Jackson Grayson, Jr., "Management Science and Business Practice," Harvard Business Review, July-August 1973. Mr. Grayson is Dean of the School of Business Administration, Southern Methodist University. He served as Chairman of the Price Commission in Phase II of the recent Economic Stabilization Program; this experience was the impulse behind his article.

2. C. West Churchman, Managerial Acceptance of Scientific Recommendations, 1967.

3. R.H. Doktor and W.F. Hamilton, "The Acceptance of Operations Research Proposals," 1971, and J.H.B.M. Huysmans, "The Effectiveness of the Cognitive Style Constraint in Implementing Operations Research Proposals," 1970. (Both appear in Management Science.)

4. P. Lawrence and J. Lorsch, Organization and Environment, 1968.

5. See especially: D.H. Broadbent, Decision and Stress, 1971; J. Bruner, J.J. Goodnow and G.A. Austin, A Study of Thinking, 1956; P.C. Wason and I. Johnson-Laird, The Psychology of Reasoning, 1972; U. Neisser, Cognitive Psychology, 1967.

6. L. Altemeyer, Education in the Arts and Sciences, unpublished doctoral dissertation, Carnegie-Mellon, 1966.

7. These experiments are described in detail in: The Implications of Cognitive Style for Individual Decision-Making, P.G.W. Keen, unpublished doctoral dissertation, Harvard Graduate School of Business Administration, 1973.

8. See: Manual for Kit of Reference Tests for Cognitive Factors, J.W. French, R.B. Ekstrom and L.A. Price, Educational Testing Service, New Jersey. The tests used here were: Identical Pictures, Concealed Figures, Verbal Puzzles, Scrambled Words, Four-letter words, Paper-folding, Choosing a Path, Controlled Associations, Object-Naming, Figure Classification, Insight Problems.

9. See: "Antecedent Probability and the Efficiency of Psychometric Signs, Patterns, or Cutting Scores," P.E. Meehl and A.E. Rosen, Psychological Bulletin, Vol. 52, No. 3, 1955.

10. See in particular: H.A. Simon and A. Newell, Human Problem-Solving, 1971.

11. I.B. Myers, The Myers-Briggs Indicator, ETS, 1962.

References -- continued

12. R.O. Mason and I.I. Mitroff, "A Program for Research on Management Information Systems," Management Science, January 1973.

13. For discussion of the SVIB, see: A. Anastasi, Psychological Testing, 1968.

14. D.H. Heany, "Is TIMS Talking to Itself?" Management Science, December 1965.

15. See: J.L. McKenney, "A Taxonomy of Problem-Solving," Working Paper, Harvard Graduate School of Business Administration, 1973.

16. Heany, op. cit., comments amusingly on this aspect of OR projects. Churchman, op. cit., similarly states that he set students to review the first six years of publication (1953-59) of Operations Research Quarterly and found that there was no evidence that any of the models discussed was ever actually used by the managers for whom it was specifically designed.

17. J.W. Botkin, An Intuitive Computer System: A Cognitive Approach to the Management Learning Process, unpublished doctoral dissertation, Harvard Graduate School of Business Administration, 1973.

18. This aspect of the formal structure of computer models is discussed in more detail in: "The Implications of Cognitive Style for the Design of Computer Models," P.G.W. Keen, Working Paper, Harvard Graduate School of Business Administration, 1972.

19. J.S. Hammond III, "The Roles of the Manager and Analyst in Successful Implementation," paper presented to the XX International Meeting of the Institute of Management Sciences, Tel Aviv, 1973.

20. Wason and Johnson-Laird, op. cit., provide substantial data on the fact that even the most intelligent individuals make frequent logical errors that are of no adverse impact due to the self-correcting nature of feedback and hypothesis-testing in thought processes.

Bibliography

The development and theory behind the model of cognitive style are discussed in a series of working papers and doctoral dissertations, all produced at the Harvard Graduate School of Business Administration:

Botkin, J.W., "An Intuitive Computer System: A Cognitive Approach to the Management Learning Process," doctoral dissertation.

Keen, P.G.W., "The Implications of Cognitive Style for Individual Decision-Making," doctoral dissertation.

Keen, P.G.W., "The Implication of Cognitive Style for the Design of Computer Models."

Keen, P.G.W. and J.L. McKenney, "The Evolution of an Experimental Design for the Study of Cognitive Style."

McKenney, J.L., "A Taxonomy of Problem-Solving."

McKenney, J.L., "Human Information-Processing."

Nelson, K.H., "A Bibliography of Cognitive Style Research."